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## Treating dispersions of acrylonitrile polymers

## Background of the invention

Acrylonitrile is the basis for a family of important commercial polymers. For example, copolymers of butadiene with less than 50% acrylonitrile provide oil resistant polymers. Copolymers of alkyl acrylates with acrylonitrile provide a range of polymer products. For example when ethyl acrylate is the major component, oil resistant elastomers are obtained; and when acrylonitrile is the predominant monomer, useful molded plastic materials are obtained. Copolymers of a major proportion of styrene and minor proportions of acrylonitrile are also useful in modifying vinyl chloride polymers, as moldable plastics and as components of ABS resin blends. Normally these acrylonitrile containing polymers are prepared by polymerization in water. Even when such polymerizations are substantially complete, there still remains undesirable amounts of unpolymerized acrylonitrile dissolved both in the polymer and the water. Normal procedures of stripping by vacuum or steam does not normally remove all of this undesirable acrylonitrile.

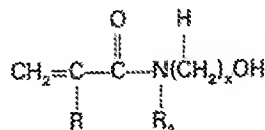
## Summary of the invention

Residual acrylonitrile dissolved in acrylonitrile homo- or copolymers and/or water in which acrylonitrile polymers are polymerized or processed such as a latex thereof or from acrylonitrile processes can be substantially reduced by adding to polymer-water mixtures, for example, after at least 90% of the monomers have been polymerized, additional catalyst and an amount of comonomer in excess of the amount of free acrylonitrile present.

## Detailed description

The aqueous suspensions or dispersions of acrylonitrile polymers used in practicing the present invention are obtained by polymerizing acrylonitrile alone, or more normally with other vinylidene comonomers to form copolymers, for example with 50 weight percent or more of butadiene, up to 50 weight percent acrylonitrile with 50—95 weight percent styrene, and 5—50 weight percent acrylonitrile with 1—99 weight percent each of an alkyl acrylate such as methyl acrylate, ethyl acrylate, butyl acrylate, methyl methacrylate with styrene and acrylonitrile on a butadiene polymer in the well-known ABS resins, and other copolymers.

Typically, the polymerizable comonomers used in addition to butadiene, styrene and an alkyl acrylate or alkacrylate wherein the alkyl group contains 1 to 8 carbon atoms, will be vinylidene monomers having at least one terminal  $\text{CH}_2=<$  group. Polymerizable comonomers useful in the present invention include: other vinyl aromatics as  $\alpha$ -methyl styrene and chlorostyrene;  $\alpha$ -olefins such as ethylene, propylene, and isobutylene; vinyl halides such as vinyl chloride, vinyl bromide, vinyl fluoride, vinylidene chloride, and vinylidene fluoride; vinyl esters such as vinyl acetate, other  $\alpha,\beta$ -olefinically unsaturated nitriles such as methacrylonitrile; alkyl vinyl ethers such as methyl vinyl ether, isopropyl vinyl ether; n-butyl vinyl ether, isopropyl vinyl ether, and haloalkyl vinyl ethers as 2-chloroethyl vinyl ether; n-octyl methacrylate, dodecyl methacrylate, methyl ethacrylate, ethyl ethacrylate, haloalkyl acrylates as chloropropyl acrylate, amino-acrylates and methacrylates; vinyl ketones; vinyl pyridine,  $\alpha,\beta$ -olefinically unsaturated amides such as acrylamide, N-methyl acrylamide, N-t-butyl acrylamide, N-cyclohexyl acrylamide, diacetone acrylamide; methacrylamide, and N-ethyl methacrylamide,  $\alpha,\beta$ -olefinically unsaturated N-alkylol amides having the structural formula



wherein R is a hydrogen or an alkyl group containing from 1 to 4 carbon atoms and x is a number from 1 to 4, R<sub>1</sub> is hydrogen or an alkyl group such as N-methylol acrylamide, N-ethylol acrylamide, N-propylol acrylamide, N-methylol methacrylamide, and N-ethylol methacrylamide; polyfunctional compounds such as methylene-bis-acrylamide, ethylene glycol dimethacrylate, diethylene glycol dimethacrylate, allyl pentaerythritol and divinyl benzene;  $\alpha,\beta$ -olefinically unsaturated carboxylic acid monomers containing from 3 to 10 carbon atoms such as acrylic acid, methacrylic acid, crotonic acid,  $\beta$ -acryloxy propionic acid, hydrosorbic acid, sorbic acid  $\alpha$ -chlorosorbic acid, cinnamic acid,  $\beta$ -styrylacrylic acid, itaconic acid, citraconic acid, maleic acid, fumaric acid, mesaconic acid, glutaconic acid and aconitic acid.

The preferred acid monomers are the  $\alpha,\beta$ -monoolefinically unsaturated monocarboxylic acids such as acrylic acid and methacrylic acid, as are known to those skilled in the art. Mixtures of one or more of the above-mentioned monomers may be employed if desired.

Generally, butadiene or alkyl acrylate polymers will contain 50 to 70% by weight butadiene, or

alkyl acrylate wherein the alkyl group contains 1 to 8 carbon atoms, 20 to 45% of acrylonitrile and up to about 20% by weight of other polymerizable vinylidene comonomers interpolymerized.

The polymer latices may be prepared using any of the conventional polymerization techniques known to those skilled in the art, usually in an aqueous emulsion. The emulsifier may be charged at the outset of the polymerization or may be added incrementally or by proportioning throughout the run. Any of the general types of anionic, cationic or nonionic emulsifiers may be employed, however, best results are generally obtained when anionic emulsifiers are used. Typical anionic emulsifiers which may be used include those types known to those skilled in the art, for example, as disclosed beginning on page 102 in J. Van Alphen's "Rubber Chemicals", Elsevier, 1956, for example, the alkali metal or ammonium salts of the sulfates of alcohols containing from 8 to 18 carbon atoms such as, for example, sodium lauryl sulfate; alkali metal and ammonium salts of sulfonated petroleum or paraffin oils; sodium salts of aromatic sulfonic acids such as dodecane-1-sulfonic acid and octadecene-1-sulfonic acid; alkyl aryl sulfonates such as sodium isopropyl benzene sulfonate and sodium dodecyl benzene sulfonate; alkali metal and ammonium salts of sulfonated dicarboxylic acid esters such as sodium dioctyl sulfosuccinate and disodium N-octadecyl sulfosuccinamate; alkali metal or ammonium salts of the free acids of complex organic mono- and diphosphate esters.

So-called nonionic emulsifiers are octyl- or nonylphenyl polyethoxyethanol. Useful as emulsifiers are the alkali metal salts of the aromatic sulfonic acids such as sodium salts of the aromatic sulfonic acids and the sodium salts of the alkyl aryl sulfonates of the formula  $R-Ar-SO_3^-M^+$  wherein R is alkyl or alkenyl having 8 to 20 carbon atoms, Ar is aryl or phenyl or naphthyl and M is the metal ion. In addition to the above-mentioned emulsifiers it may be desirable and advantageous to add post-polymerization emulsifiers and stabilizers to the polymeric anionic latex in order to improve the latex stability if it is to be stored for prolonged periods prior to use. Such post-polymerization emulsifiers may be the same as, or different than, the emulsifier employed in conducting the polymerization but preferably are anionic or non-ionic surface active agents.

To initiate the polymerization free radical catalysts are employed. The use of such catalysts, although in certain systems not absolutely essential, insure a more uniform and controllable polymerization and a satisfactory polymerization rate. Commonly used free radical initiators include the various peroxygen compounds such as the persulfates, organic peroxides, benzoyl peroxide, t-butyl hydroperoxide, cumene hydroperoxide; azo compounds such as azobisisobutyronitrile, and dimethyl azodisobutyrate. Especially useful as polymerization initiators are the water-soluble peroxygen compounds such as hydrogen peroxide and the sodium, potassium and ammonium persulfates.

The alkali metal and ammonium persulfate catalysts may be employed by themselves or in activated redox systems. Typical redox systems include the persulfates in combination with: a reducing substance such as a polyhydroxy phenol and an oxidizable sulfur compound such as sodium sulfite or sodium bisulfite, a reducing sugar, a diazomercapto compound, a ferricyanide compound and dimethyl-aminopropionitrile. Heavy metal ions such as silver, cupric, iron, cobalt, nickel and others may also be used to activate persulfate catalyzed polymerizations. The well known redox systems using organic peroxides and organic hydroperoxides may also be used advantageously. In general the amount of free radical initiator employed will range between 0.1 to 5% based on the weight of the total monomers. The initiator is generally completely charged at the start of the polymerization, however, incremental addition or proportioning of the initiator throughout the polymerization is often desirable. In conducting the polymerization for the preparation of the latices—the possible starting materials of the present invention—the monomers are typically charged into the polymerization reactor which contains the water and the emulsifying agent. The reactor and its contents are then heated and the polymerization initiator added. The temperature at which the polymerization is conducted is not critical and may range from 0°C or lower to 85°C or higher. Excellent results, however, have been obtained when the polymerization temperature is maintained between 5°C and 60°C. Polymerization modifiers such as the primary, secondary, and tertiary mercaptans, buffers and electrolytes may also be included in the polymerization.

In the practice of the invention, when at least 90% of the monomers have copolymerized, more preferably after 93—95% monomers have been copolymerized, there is added to the polymerization mixture an amount of the comonomer being polymerized with acrylonitrile preferably in excess of the unpolymerized acrylonitrile, and additional catalyst, to induce copolymerization of said comonomer with the acrylonitrile effectively to decrease the amount of free residual acrylonitrile below 100 parts per million; more preferably below 25 parts per million. While the most effective comonomer amount that can be added may be used, there is a practical maximum amount in adding only a sufficient amount to insure reaction with substantially all of the free acrylonitrile to reduce the problem of loss or recovery of the excess comonomer. Normally an amount from equimolar to 50 mole percent excess to the acrylonitrile will be satisfactory.

The catalyst employed is preferably one that will complete the reaction in a matter of only a few hours. The redox catalysts are well known and may be used that involve the use of a combination reducing agent and peroxy catalyst, for example, heavy metal compounds such as ferrous iron or cobalt are generally effective with organic peroxides such as capryloyl peroxide, lauroyl peroxide, cumene hydroperoxide and diisopropyl benzene hydroperoxide. Also useful in such systems are polyhydroxy

ketones such as the sugars with ferrous salts and cumene hydroperoxide. Gluconates have also been found to be useful. Other effective active catalyst systems include persulfate-bisulfite systems; peroxamine; saponamine and diazothioether catalyst systems, as are well known in the art, including those set forth hereinabove. Of course any catalyst system may be used, for example even sodium persulfate and hydrogen peroxide, but normally on a production basis it is desirable that equipment be tied up as short a period as possible for this step, so that the more active catalysts are employed to obtain faster reaction rates and equipment turn around. Other known catalysts such as potassium persulfate may be used if longer reactions are acceptable.

The acrylonitrile level may be decreased in accordance with the invention by adding the excess comonomer and catalyst in the reactor after 90% conversion has been reached, in blow-down, hold or storage tanks after removal from the polymerization reactor; or in any suitable container preferably equipped with agitation and heating means. In the selection of comonomer, it will be understood that in polymer dispersions of high conversion a different monomer may be introduced for reaction with the acrylonitrile in those situations where small amounts of another copolymer are not undesirable. For example, in the preparation of a copolymer of styrene and acrylonitrile where at the end of the polymerization there are present several thousand or more parts of unreacted acrylonitrile a redox catalyst and butadiene-1,3 or ethyl acrylate may be added to the polymerization and the acrylonitrile removed by reaction with the butadiene or acrylate and the small amount of copolymer thus formed would normally be mixed in with the copolymer of styrene and acrylonitrile in such amounts as to be not undesirable. Butadiene is a particularly useful monomer and would be used to reduce the acrylonitrile level of polymer dispersions since it reacts readily with acrylonitrile, particularly when present in an excess, and because of its low boiling point of about  $-4^{\circ}\text{C}$ , it is easily and efficiently removed from the polymer dispersion without expensive or extensive processing.

As stated, any catalyst system effective in the copolymerization of acrylonitrile with other monomers at reasonable temperatures, in the range of 5 to  $95^{\circ}\text{C}$ , more preferably 20 to  $50^{\circ}\text{C}$ , may be used. When butadiene is used as the reactive comonomer for decreasing the level of acrylonitrile the amount present should be in excess; for example, the butadiene level should be greater than the combining ratio or combining weight of butadiene with acrylonitrile, which is 63 to 37. The amount of catalyst employed based on the peroxy compound, preferably is an amount at least about 0.10 part peroxy compound based on the total monomer and polymer present.

With effective redox type catalyst systems, a temperature range of 25 to  $50^{\circ}\text{C}$  is satisfactory to provide reaction rates of 3 to 5 hours with a resulting amount of residual acrylonitrile obtained of less than 100 ppm (mg/kg). In other words, reaction temperatures of room temperature to  $60^{\circ}\text{C}$  which are normal polymerization temperatures for the aqueous polymerization of acrylonitrile polymers are satisfactory.

#### Example

A copolymer of butadiene and acrylonitrile was prepared in water to form a latex in accordance with the recipe set forth in the Table below. With the exception of the control, additional butadiene and catalyst were added to the polymerization mixture after the monomers had reached a conversion to polymer of approximately 95%. All parts were parts by weight. The results in residual acrylonitrile after treatment were set forth in the Table. Run A was the control, with no addition of butadiene or catalyst. Run B demonstrates the ineffectiveness of catalyst alone without the comonomer. Raising the temperature of the control from the polymerization temperature of  $35^{\circ}\text{C}$  to  $72^{\circ}\text{C}$  for two hours did not result in any decrease in residual acrylonitrile. The temperature was also raised in Run B with no resultant decrease in acrylonitrile content after several hours at the elevated temperature. In Runs C and D a second butadiene and catalyst addition was made after the initial addition and as shown in Run F where no second addition was made, such second addition is normally not necessary.

On a production scale butadiene/acrylonitrile copolymer latex is prepared, which after conversion was essentially complete, contained about 8000 to 15000 ppm of free acrylonitrile. There was added to the latex 5 parts of water containing 0.001 phr of sodium hexahydroxyheptanate, 0.001 phr of sodium ferric ethylenediamine tetraacetic acid salt, 0.001 phr of trisodium ethylenediaminetetraacetic acid salt, 0.1 phr of sodium formaldehyde sulfoxylate, and 0.1 phr of sodium sulfite, 5 phr of butadiene-1,3 and 0.2 phr of cumene hydroperoxide (0.3 of 70% cumene hydroperoxide) at a temperature of about  $35^{\circ}\text{C}$ . After about 4 hours, the residual or free acrylonitrile had been reduced to an average of about 50 ppm.

When similar tests are conducted with latices containing for example, 20% total solids of a polymer of acrylonitrile containing unreacted acrylonitrile; an ABS latex containing free acrylonitrile; and an ethyl acrylate-acrylonitrile copolymer latex, treated respectively with additional styrene or butadiene-1,3, butadiene-1,3 or ethyl acrylate where appropriate, with a redox catalyst, the amount of free acrylonitrile is substantially reduced to less than 100 ppm.

TABLE I

Recipe	A	B	C	D	E	F
$\text{NaHCO}_3$	0.2	0.2	0.2	0.2	0.2	0.2
Butadiene-1,3	55	55	55	55	55	55
Acrylonitrile	45	45	45	45	45	45
Bis(isopropyl xanthogen disulfide)	1.0	1.0	1.0	1.0	1.0	1.0
Water	150	150	150	150	150	150
Potassium soap of tallow acid	5.0	5.0	5.0	5.0	5.0	5.0
$\text{Na}_2\text{S}_2\text{O}_4$	0.04	0.04	0.04	0.04	0.04	0.04
$\text{K}_2\text{S}_2\text{O}_8$	0.3	0.3	0.3	0.3	0.3	0.3
Daxad 17 <sup>(1)</sup>	1.0	1.0	1.0	1.0	1.0	1.0
Sequesterene $\text{NA3}^{\text{®}}$ <sup>(2)</sup>	0.03	0.03	0.03	0.03	0.03	0.03
Sodium hexahydroxyheptanate	0.02	0.02	0.02	0.02	0.02	0.02
Dimethylamine	0.02	0.02	0.02	0.02	0.02	0.02
Post polymerization addition						
Butadiene-1,3	0	0	6.0 g	10.0 g	6.0 g	11.5 g
Sequesterene $\text{NA3}^{\text{®}}$ <sup>(2)</sup>	0	0.001	0.001	0.001	0.001	0.001
Sequesterene $\text{NAFe}^{\text{®}}$ <sup>(3)</sup>	0	0.001	0.001	0.001	0.001	0.001
Sodium hexahydroxyheptanate	0	0.001	0.001	0.001	0.001	0.001
$\text{Na}_2\text{S}_2\text{O}_4$	0	0.15	0.15	0.15	0.15	0.15
Water	0	5.0	5.0	5.0	5.0	5.0
Diisopropylbenzene hydroperoxide	0	0.1	0.1	0.1	0.1	0.1
Results of post-polymerization additions						
First addition, phm <sup>(4)</sup>						
Butadiene	None	None	6	11.5	6	11.5
SFS <sup>(5)</sup>	None	0.15	0.15	0.15	0.15	0.15
DIP <sup>(6)</sup>	None	0.1	0.1	0.1	0.1	0.1
Second addition, phm						
Butadiene	None	None	6	12	10.5	None
SFS <sup>(5)</sup>	None	0.15	0.15	0.15	—	—
DIP <sup>(6)</sup>	None	0.1	0.1	0.1	0	0
Residual acrylonitrile, mg/kg (ppm)	18,300	16,600	10	6	8	10

<sup>(1)</sup> Sodium salt of condensed naphthalene sulfonate-formaldehyde<sup>(2)</sup> Trisodium ethylenediaminetetraacetate (Ciba Geigy)<sup>(3)</sup> Sodium iron ethylenediaminetetraacetate (Ciba-Geigy)<sup>(4)</sup> phm—Parts per hundred of polymer<sup>(5)</sup> Sodium formaldehyde sulfoxylate<sup>(6)</sup> Diisopropylbenzene hydroperoxide

## Claims

1. A method for reducing the residual acrylonitrile dissolved in acrylonitrile homo- or copolymer and/or water comprising adding to said acrylonitrile polymer and/or water a comonomer  
5 copolymerizable with acrylonitrile and a catalyst for inducing copolymerization of said comonomer with said residual acrylonitrile.
2. The method of Claim 1 wherein said acrylonitrile polymer and/or water is a latex of an acrylonitrile polymer, said acrylonitrile polymer having been converted from monomers to polymer to  
10 greater than 90% conversion.
3. The method of Claim 2 wherein the amount of said comonomer added is in excess of the amount of residual acrylonitrile present in said latex.
4. The method of Claim 3 wherein said acrylonitrile polymer is a copolymer of butadiene and acrylonitrile, said comonomer is butadiene and is added in an amount to provide a weight ratio of  
15 added butadiene to residual acrylonitrile which is greater than 83 to 37, said catalyst is a redox catalyst, and said conversion is greater than 93%.
5. The method of Claim 4 wherein said redox catalyst consists of an organic peroxide and a reducing heavy metal compound.
6. The method of Claim 4 wherein the temperature of addition of butadiene and redox catalyst is between 25 to 60°C and the amount of residual free acrylonitrile resulting is less than 100 ppm.
- 20 7. The method of Claim 4 wherein the amount of butadiene and acrylonitrile initially copolymerised is from 60 to 80 weight percent butadiene-1,3 and 20 to 40 weight percent acrylonitrile.

## Patentansprüche

1. Verfahren zur Verringerung des in einem Acrylnitril-Homo- oder -Copolymerisat und/oder  
25 Wasser gelösten restlichen Acrylnitrils, dadurch gekennzeichnet, daß zu dem Acrylnitril-Homo- oder -Copolymerisat und/oder Wasser ein Comonomer, das mit Acrylnitril copolymerisierbar ist, und ein Katalysator zur Induzierung der Copolymerisation des Comonomeren mit dem restlichen Acrylnitril  
30 zugesetzt wird.
2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Acrylnitril-Polymerisat und/oder Wasser ein Latex eines Acrylnitril-Polymerisats ist, wobei das Acrylnitril-Polymerisat mit einem Umwandlungsgrad von mehr als 90% aus Monomeren in das Polymer überführt wurde.
3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß das Comonomer in einer  
35 Überschuß-Menge über die Menge des in dem Latex vorhandenen restlichen Acrylnitrils zugesetzt wird.
4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß das Acrylnitril-Polymerisat ein Copolymerisat aus Butadien und Acrylnitril ist und das Comonomer Butadien ist und in einer Menge zugesetzt wird, so daß ein Gewichtsverhältnis des zugesetzten Butadiens zu dem restlichen Acrylnitril  
40 erhalten wird, das größer ist als 83 zu 37, wobei der Katalysator ein Redox-Katalysator ist und der Umwandlungsgrad größer als 93% ist.
5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der Redox-Katalysator aus einem organischen Peroxid und einer reduzierenden Schwermetall-Verbindung besteht.
6. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß die Temperatur, bei der das Butadien und der Redox-Katalysator zugesetzt werden, zwischen 25°C und 60°C liegt und die  
45 resultierende Menge des restlichen freien Acrylnitrils weniger als 100 ppm beträgt.
7. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß die Mengen des anfänglich copolymerisierten Butadien und Acrylnitrils 60 bis 80 Gew.-% Butadien-1,3- und 20 bis 40 Gew.-% Acrylnitril betragen.

## Revendications

1. Procédé pour réduire la quantité d'acrylonitrile résiduel dissous dans un homopolymère ou un copolymère d'acrylonitrile et/ou dans l'eau, consistant à ajouter audit polymère d'acrylonitrile et/ou à  
55 l'eau un comonomère copolymérisable avec l'acrylonitrile et un catalyseur déclenchant la copolymérisation dudit comonomère avec ledit acrylonitrile résiduel.
2. Procédé suivant la revendication 1, dans lequel le polymère d'acrylonitrile et/ou l'eau représentent un latex d'un polymère d'acrylonitrile ledit polymère d'acrylonitrile ayant été converti en polymère à partir de monomères à un degré de transformation de plus de 90%.
3. Procédé suivant la revendication 2, dans lequel la quantité ajoutée de comonomère est en  
60 excès par rapport à la quantité d'acrylonitrile résiduel présente dans ledit latex.
4. Procédé suivant la revendication 3, dans lequel ledit polymère d'acrylonitrile est un copolymère de butadiène et d'acrylonitrile, ledit comonomère est le butadiène et il est ajouté en une quantité correspondant à un rapport en poids du butadiène ajouté à l'acrylonitrile résiduel supérieur à 83:37, ledit catalyseur est un catalyseur d'oxydoréduction et ledit degré de transformation est supérieur à  
65 93%.

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5. Procédé suivant la revendication 4, dans lequel le catalyseur d'oxydoréduction consiste en un peroxyde organique et en un composé réducteur de métal lourd.

6. Procédé suivant la revendication 4, dans lequel la température d'addition du butadiène et du catalyseur d'oxydoréduction se situe entre 25 et 60°C et la quantité d'acrylonitrile libre résiduel  
5 résultante est inférieure à 100 ppm.

7. Procédé suivant la revendication 4, dans lequel la quantité de butadiène et d'acrylonitrile initialement copolymérisés est de 60 à 80% en poids de butadiène-1,3 et de 20 à 40% en poids d'acrylonitrile.

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